R E P O R T R E S U M E S

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IDENTIFICATION OF GIFTED ELEMENTARY SCHOOL CHILDREN WITH EXCEPTIONAL SCIENTIFIC TALENT.

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REPORT NUMBER CRP-392 PUB DATE 1 SEP 60
EDRS PRICE MF-$0.18 HC-$2.56 64P.

DESCRIPTORS- *IDENTIFICATION, ABILITY IDENTIFICATION, ELEMENTARY SCHOOL STUDENTS, GIFTED, SUPERIOR STUDENTS, *TALENTED STUDENTS, *SCIENCES, *TEST CONSTRUCTION, *PREDICTIVE VALIDITY, GRADE 3, NEW YORK, NEW YORK CITY, HUNTER SCIENCE APTITUDE TEST

A TEST OF SCIENCE APTITUDE WAS CONSTRUCTED AND PRELIMINARY EVIDENCE OF ITS VALIDITY OBTAINED BY INDIVIDUAL ADMINISTRATION TO 58 GIFTED, 6- AND 7-YEAR-OLD CHILDREN. TWO FORMS OF A 91-ITEM HUNTER SCIENCE APTITUDE TEST WERE CONSTRUCTED. ITEMS INCLUDED IN THESE TESTS WERE DESIGNED TO MEASURE THE ABILITY--(1) TO RECALL SCIENTIFIC INFORMATION, (2) TO ASSIGN MEANINGS TO OBSERVATIONS, (3) TO APPLY SCIENTIFIC PRINCIPLES IN MAKING PREDICTIONS, AND (4) TO USE THE SCIENTIFIC METHOD. THE TESTS WERE ADMINISTERED AT THE BEGINNING OF THE SCHOOL YEAR AND DURING THE YEAR AT THE COMPLETION OF SEVEN DIFFERENT SCIENCE UNITS. A SINGLE-WEIGHTED, COMPOSITE SCIENCE ACHIEVEMENT SCORE WAS THUS OBTAINED FROM EACH SUBJECT. THE PARALLEL-FORMS RELIABILITY COEFFICIENT OF THE HUNTER SCIENCE APTITUDE TEST AND THE RELIABILITY OF THE WEIGHTED COMPOSITE SCIENCE ACHIEVEMENT SCORE WERE FOUND TO BE SOMEWHAT LOWER THAN EXPECTED. HOWEVER, THE PREDICTIVE VALIDITY CORRELATION COEFFICIENTS WERE EXTREMELY HIGH, BECAUSE THE APTITUDE TESTS AND THE SCIENCE ACHIEVEMENT CRITERION THAT WERE USED OVERLAPPED THE KINDS OF ABILITY AND CONTENT MEASURED. BOTH WERE MODELED UPON THE CONTENT OF THE THIRD-GRADE SCIENCE CURRICULUM. RESEARCH EXTENSIONS WERE RECOMMENDED IN TIME AND SCOPE OF THE CRITERIA, AS WELL AS IN ADDITIONAL VALIDATION STUDIES. (JH)

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Identification of Gifted Elementary School Children With Exceptional Scientific Talent

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ED002864

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THE IDENTIFICATION OF GIFTED ELEMENTARY SCHOOL CHILDREN WITH EXCEPTIONAL SCIENTIFIC TALENT

A Cooperative Research Project of Hunter College and the United States Office of Education under U. S. Office of Education Contract No. 392.

September 1, 1958 - August 31, 1960

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Introduction

Recent international events have focused attention upon the urgent need for early identification of exceptional science talent. The scarcity of skilled scientific personnel and the inability of our schools to capitalize fully upon the science potential of students emphasizes the demand for early recognition of science ability. The purpose of this research is to construct an instrument through which accurate selection of young, scientifically gifted children may be achieved. The specific hypothesis to be tested is that measures of exceptional science talent which will allow prediction of scientific achievement can be constructed and utilized with a third-grade elementary school population.

In recent decades, several extensive programs have been established at the secondary school and college levels for the identification and training of students with superior ability in science. Among the projects that have shown promise in the prediction and development of science ability are the

Annual Science Talent Search (Edgerton and Britt, 1944, 1947), the National Merit Scholarship Program (National Merit Scholarship Corporation, 1959), the Longitudinal Study of Career Development of Scientists (Cooley, 1958, 1959), and the Joint Program for Technical Education (Joint Program for Technical Education, 1957). Many other valuable contributions (e.g., U. S. Office of Education, 1952; Seashore, 1952) have been made to the development of techniques for the selection of secondary school and college students with science potential.

However, efforts to identify science aptitude should not be restricted to secondary school and college levels. The earlier the identification of students with science potential can be accomplished, the more encouragement and guidance these students can be given.

Much of the literature concerning science talent has centered upon two questions: (1) does science aptitude represent a single, clearly defined entity? and (2) if science aptitude is to some degree a circumscribed, unitary variable, what are its distinguishing component characteristics? Certain investigators (e. g., Davis, 1951; Fehr, 1953; Guilford, 1950; Subarsky, 1948), describing mainly the abilities of secondary school children, contend that there is a clearly defined

trait of science aptitude, analogous to musical and artistic aptitudes. There is much disagreement, however, in the specification of the components of this science aptitude. Guilford (1950), for example, emphasizes sensitivity to problems, ability to develop novel ideas, and the ability to evaluate. Subarsky (1948) stresses specialized and persistent curiosity, alertness in detecting inconsistencies, and a high degree of mechanical-mindedness. Cole (1956) enumerates the characteristics of industry, devotion to work, energy, and initiative among the components of science aptitude, while Super and Bachrach (1957) list spatial visualization, manipulative ability, ability to plan and design a study, and ability to communicate.

Other authorities (e.g., Brandwein, 1951, 1955) argue that there is no single trait of science talent per se, but that science talent is one aspect of high general intelligence which emerges through environmental stimulation and available opportunities for development. Edgerton (1959), Roe (1952), MacCurdy (1956) and others have referred to the personality and developmental influences in science ability. Cooley (1958) suggests that there is no isolated, unitary set of characteristics which distinguishes science aptitude and recommends multivariate,

longitudinal analyses of personality, social, and motivational variables in the study of science ability.

However, even those investigators (e.g., Freeman, 1955) who regard science aptitude as a multidimensional conglomerate of variables agree that prediction of success in scientific studies and occupations is feasible through the consideration of the correct combination of variables. The prediction of science achievement by tests of science aptitude does not necessarily imply that such a science aptitude test measures psychological functions which are essentially different from those used in other types of mental activity.

Despite the wide differences among researchers regarding the nature and distinguishing features of science aptitude, the results of an earlier study (Davis, Lesser, French et al., 1959), performed with the cooperation of the U. S. Office of Education by the present authors, encourage further work upon the development of techniques for measuring science aptitude in young children. This study measured knowledge of scientific principles and information as well as space conceptualization, vocabulary, number ability, and reasoning in groups of children five and six years of age. This measure

of scientific knowledge displayed adequate reliability (split-half reliability coefficient of +.79) despite the low age level of the subjects. In addition, intercorrelations among these measures indicated that the test of knowledge of scientific principles and information yielded a substantial percentage of nonchance variance estimated to be unique among the five tests employed. Also, the results of this earlier investigation supplied some evidence that five-year-old children selected as outstanding in science ability, on a preliminary form of the tests constructed in this research, respond differently to scientific material presented in the classroom when compared with other children.

Thus, there was some preliminary evidence that science aptitude could be reliably identified in young children. The present research constructed and evaluated an instrument for measuring science aptitude in children six and seven years of age.

Characteristics of the Hunter Science Aptitude Test

Two forms of a 91-item Hunter Science Aptitude Test were constructed. The outline of the test is presented below, with a tabulation of the number of items in each sub-test

Scientific Aptitude--Behavior Objectives	FORM AX		FORM BX	
	Items in Groups	Single Items	Items in Groups	Single Items
I. Ability to recall information				
A. Knowledge of scientific vocabulary	3	2	3	2
B. Knowledge of scientific principles	3	5	3	5
C. Knowledge of tools and scientific instruments	2	4	2	4
D. Knowledge about the natural environment	11	5	11	5
II. Ability to assign meanings to observations				
A. Formulation or verbalization of a principle to explain an effect described	8	5	8	5
B. Identification of crucial elements of a problem	5	5	5	5
III. Ability to apply principles in making predictions				
A. Utilization of available information in novel situations	2	3	2	3
B. Utilization of a scientific principle in a familiar situation	5	6	5	6
C. Analysis of the factors influencing predictions	5	6	5	6
IV. Ability to use the scientific method				
A. Planning steps leading to a solution	2	4	2	4
Total:	46	45	46	45

category. The item categories were established through (1) the selection of the components of science aptitude about which there is consensus of agreement in the literature, and (2) the inclusion of abilities which were appropriate to the population of six- and seven-year-old children.

The 182 items included in the two forms of the Hunter Science Aptitude Test were selected from a pool of 330 items which were written, edited, and tried out on preliminary samples of second-grade and third-grade children at Hunter College Elementary School and Public School 40, Manhattan.

The test outline indicates that items were divided into "items in groups" and "single items." The "items in groups" were developed for experimental use in order to assess the abilities listed in category III (ability to apply principles in making predictions) and category IV (ability to use the scientific method) listed in the test outline. These "items in groups" are presented in a serial arrangement; there are 12 series of from 3 to 5 items each in Form AX and in Form BX. Thus, in each form, 46 items of the 91 are arranged in groups. A sample series from Form BX, with the general instructions for administration and scoring key, is presented in Appendix A. This serial method of presentation, in which a

child is tested for his ability to learn new material at the same time that his prior knowledge of material is being tested, permits assessment of the child's ability to combine elements into principles as well as his ability to apply the scientific method. The basic premise underlying this form of testing is that, with very young children, the ability to organize available facts into a meaningful concept is at least as indicative of scientific aptitude as is the sheer number of facts that have been accumulated.

In this serial testing arrangement, if the child answers incorrectly or does not know the answer to one or more of the first three items in the group, it is scored as incorrect, and then the answer is explained to him. This explanation, like the question, is in prescribed form (see sample series in Appendix A). Each item is scored correct or incorrect before the explanation is given by the examiner. Thus, items early in each series measure information that the child acquired prior to the test situation, while the solution of later items in the series requires comprehension of the explanation given to the previous items in the series and the application of the explanation to a new situation. Thus, this technique of presenting items in meaningful groups permits

scoring pupils on their knowledge of facts while providing them with facts they need for educing principles. They are then scored on their ability to educe principles on the basis of the facts they have already known or have been told during the testing.

Two judges independently assigned each of the 182 items in the Hunter Science Aptitude Test to the categories presented in the test outline. The degree of inter-judge agreement in categorising items is indicated in a Coefficient of Concordance (W) of $\pm.80$ ($p < .001$).

In addition to including test content and materials appropriate to the identification of science aptitude in young children, other requirements were considered in construction of the Hunter Science Aptitude Test. First, since the children tested were 6 and 7 years of age, it appeared necessary to construct tests that would be administered individually. Individual administration allowed for variations in the examiner's attitudes, provided the motivation that skilled examiners can engender through personal contact, and reduced errors of measurement owing to distraction in young children. Second, an attempt was made to maintain the child's interest by including a variety of pictorial material and a number of

items which allowed the child to manipulate test objects. A third essential requirement was that the test items require no reading on the part of the examinee. This represented an attempt to eliminate any effect on the scores attributable to the wide individual differences that exist among 6- to 7-year-old children in reading ability. Fourth, all directions and explanations were worded as simply and directly as possible, and as many of the words that children themselves were found to use were incorporated in the wording of directions, items and explanations. Finally, all tests were unspeeded. This requirement excluded the effects of individual differences among the children in reaction time, ability to manipulate materials, etc.

Both forms of the Hunter Science Aptitude Test were administered to the 58 children in the third grade at Hunter College Elementary School. The tests were given just prior to and at the beginning of the school year 1959-1960; all testing was completed before formal science lessons began. Because of the time pressures involved in scheduling the administration of 116 tests within a two-week period, the different forms of the test were administered to each child by different examiners. Each session required about one hour of testing time. These

tests were scored and kept confidential by one of the investigators (FHD). In order to eliminate any chance of contamination between the Hunter Science Aptitude Test and the criterion measures obtained during the course of the school year, neither anyone in the Hunter College Elementary School nor the other investigator (OSL), who was responsible for the planning, administration, and scoring of the criterion measure, had any knowledge of the Hunter Science Aptitude Test scores.

Population

For many years Hunter College has operated demonstration schools for children from preschool through secondary school. These schools, the Hunter College Elementary School and the Hunter College High School, are devoted to the education of intellectually gifted children. The subjects employed in this experiment were the 58 children (25 boys and 33 girls) in the two third-grade classes at Hunter College Elementary School. These children ranged in age from 6 years 9 months to 7 years 9 months in the fall of the academic year when the Hunter Science Aptitude Tests were administered. Their Stanford-Binet (1937 Revision) Intelligence Quotients ranged from 136 to 171, with a median score of 151. The children come from widely distributed areas within Manhattan, N. Y., but

their families constitute a relatively homogeneous middle-class group. The total school population of Hunter College Elementary School has been described in detail elsewhere (Brumbaugh and Roshco, 1959; Hunter College Elementary School, 1959).

Results

Hunter Science Aptitude Test: Each response to the Hunter Science Aptitude Test items was assigned a score of 2, 1, or 0. The maximum range of scores on each form of the test is therefore from 0 to 154. The actual scores for Form AX ranged from 46 to 131, with a mean of 77.83 and a standard deviation of 19.40. For Form BK the scores ranged from 26 to 115, with a mean of 70.17 and a Standard deviation of 23.26. The variances of Form AX and Form BK are not significantly different at the 5 per cent level ($F = 1.44$; $n_1 = n_2 = 57$).

The parallel-form reliability coefficient for Forms AX and BK was computed; the Pearson product-moment correlation coefficient is +.64. Despite the fact that the variances of the two forms were not significantly different, Angoff's equation No. 6 (Angoff, 1953, p. 4) was applied in order to estimate the reliability of each form of the test separately from the correlation between the parallel forms and their

variances. Form AK manifests a reliability coefficient ($r_{AA} = +.61$) somewhat lower than Form BK ($r_{BB} = +.67$).

Given the length of the Hunter Science Aptitude Test, these appear to be unusually low reliability coefficients. The low average age of the children tested, the fact that different examiners administered the two forms of the test, and the difficulty of many of the items may have been contributing factors in producing this low reliability coefficient.

Difficulty levels for each item were determined. These difficulty levels may range from 0 to 2 for each item; items with difficulty levels close to 1.0 will be retained in the revised Hunter Science Aptitude Test for use with populations similar in age and intelligence to the population used in this research.

Predictive Validity Criterion--The Science Achievement Tests: Hunter College Elementary School provides unique facilities and teaching conditions for the study of science at the elementary school level. Laboratory tables, built along dimensions suitable to young children, are available for children at all grade levels; at these laboratory tables, children can individually manipulate equipment and apparatus and conduct their own experiments under the science teacher's

guidance. A science specialist teaches this subject to all elementary school grades. Lectures, demonstrations, and individual experimentation are all combined in the science curriculum. One hour per week is devoted to science in the third-grade classes used in this research.

For example, in the study of Archimedes Principle, each child is able individually to manipulate a scale, weights, a water container, and other necessary apparatus. Each child learns to measure the weight of water displaced by weighing various objects in air and in water, measuring the water in drip can and catch can, etc. The availability of such laboratory resources makes the study of science, taught by a specialist, an intensive learning experience for the 6- and 7-year-old children employed in this research.

The criterion used in this study was a weighted composite of objective test scores in science achievement obtained by each child throughout the course of the school year. Seven science achievement tests were especially constructed to evaluate the child's learning of the following topics covered in 30 one-hour class sessions. After the last class session devoted to a particular topic, the appropriate science achievement test was administered. The topics covered were:

I. Water: Its Importance in the World; Techniques for Purification (4 sessions).

II. Water: How Water is Used for Cleaning Purposes (4 sessions).

III. Water: Forms in Which Water Appears in Air (3 sessions).

IV. Water: Archimedes Principle (7 sessions).

V. Water: Water Pressure; Water Seeks Its Own Level; the Cartesian Diver (4 sessions).

VI. Water: Surface Tension, Cohesion and Adhesion (5 sessions).

VII. Sound: Vibration and Transmission (3 sessions).

Seven objective examinations (including 140 items in all) were constructed to measure the subjects' achievement in these areas. These objective examinations included multiple-choice (three-choice) and true-false items. Each test was group administered to approximately 15 children at one time; thus, each achievement test was presented in four separate sessions. Each item was read twice to the children, and, in the case of the multiple-choice items, the response alternatives were written upon the blackboard as well as

read aloud. Before the administration of the first achievement test, a brief practice period acquainted the children with the form of the testing. This form of testing was employed throughout the course of seven achievement tests and no mechanical difficulties were encountered in the children's ability to understand and follow the directions and content of the questions. The seven achievement examinations, with their scoring keys, are presented in Appendix B.

The range, mean, standard deviation, and odd-even reliability coefficient[1] are presented for each science achievement test in Table 1.

The intercorrelations (Pearson product-moment correlation coefficients) among these science achievement tests are presented in Table 2.

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[1] Pearson product-moment half-test correlation coefficient, corrected by means of Angoff equation No. 16 (Angoff, 1953, p. 7).

Table 1

Ranges, Means, Standard Deviations, and Odd-Even Reliability Coefficients for Science Achievement Tests

	Actual Score Range	N	Mean	Standard Deviation	Reliability Coefficient
Unit I	10 - 19	54	14.53	1.96	+.34
Unit II	10 - 20	56	16.27	2.02	+.74
Unit III	12 - 22	56	17.00	2.41	+.53
Unit IV	11 - 18	57	14.18	1.57	+.39
Unit V	7 - 16	55	12.22	1.87	+.51
Unit VI	10 - 19	55	14.45	2.29	+.52
Unit VII	8 - 18	54	15.00	2.00	+.41

Table 2

Intercorrelations Among Science Achievement Tests*

	Unit I	Unit II	Unit III	Unit IV	Unit V	Unit VI	Unit VII
Unit I							
Unit II	≠.22						
Unit III	≠.54	≠.37					
Unit IV	≠.44	≠.24	≠.29				
Unit V	≠.23	≠.23	≠.43	≠.46			
Unit VI	≠.33	≠.29	≠.43	≠.35	≠.41		
Unit VII	≠.33	≠.21	≠.51	≠.30	≠.28	≠.18	

*When N = 58, an intercorrelation of ≠.26 is significantly different from zero at the 5 per cent level; an intercorrelation of ≠.34 at the 1 per cent level.

In order to obtain a single, composite score for each subject from the seven science achievement tests for use as a criterion with which to correlate the Hunter Science Aptitude Test scores, each of the child's seven raw science achievement scores was multiplied by a weight based on the number of classroom sessions (listed in the outline of science content covered) devoted to the science area tested. These weights and the percent of total variance contributed by each test to the composite total score are

presented in Table 3. The seven weighted raw scores were then summed to obtain a single, composite science achievement score for each child. The weighted science achievement scores ranged from 9.7 to 32.5, with a mean of 19.23 and a standard deviation of 5.07. The scoring weights and the percent of total variance contributed by each science achievement test are presented in Table 3. The close correspondence between the percent of class time devoted to each unit and the percent of composite-score variance contributed by it is obvious.

The reliability coefficient of the weighted composite scores was obtained algebraically by using the variances, weights, and intercorrelations of the science achievement test scores in a specific application of the general formula for computing the product-moment correlation coefficient between two sets of weighted sums (Davis, 1945, Equation 16). It proved to be .82. It may be noted that Test IV was the second least reliable test ($r_{tt} = .39$, see Table 1); and yet was weighted heaviest in the composite (23% of variance, see Table 3). This fact is one reason why the reliability of the weighted composite scores is not greater than .82.

Table 3

Percent of Class Time Devoted to Each Science Unit, Scoring Weights, and the Percent of Total Variance Contributed by Each Science Achievement Test To the Composite Total Score Used as the Criterion

	Raw Score Weight	Percent of Total Variance	Percent of Class Time Devoted to Unit
Unit I	.51	13	13
Unit II	.59	14	13
Unit III	.29	10	10
Unit IV	1.02	23	23
Unit V	.53	13	13
Unit VI	.57	17	17
Unit VII	.45	10	10

Relationships between Hunter Science Aptitude Test and Science Achievement Tests: The predictive validity of the Hunter Science Aptitude Test was estimated by computing Pearson product-moment correlation coefficients between scores on each of the two forms of the test and the weighted composite scores derived from the seven science achievement tests adm administered during the course of the school year. For Form AX this coefficient is $\neq .77$ ($df = 56$, $p < .01$); for Form BX it is $\neq .74$ ($df = 56$, $p < .01$). These are exceptionally high

validity coefficients even when the time interval between the administration of the predictor tests (Forms AX and BX) and the criterion tests (Units I through VII) was as little as from 2 to 8 months. In fact, when the two validity coefficients are corrected for attenuation, using the parallel-forms reliability coefficients of Forms AX and BX and the odd-even reliability coefficient for the weighted composite score, the resulting coefficients are 1.06 for Form AX and 1.00 for Form BX. These coefficients probably represent slight overcorrections because the parallel-forms reliability estimates for Forms AX and BX take into account error variance resulting from day-to-day variations in the children's performances as well as inter-examiner variability. The correction for attenuation formula assumes reliability estimates that exclude both these sources of error variance. In any event, neither corrected coefficient is significantly greater than unity. Nonetheless, the data suggest that the predictive validity of Forms AX and BX is about as high as it can be, given their reliabilities and that of the criterion.

A second, independent predictive criterion was available in the science teacher's estimate of the science

ability of each child. During the middle of the school year, the science teacher ranked the children in the two classes separately for their demonstrated ability in class to learn science information and principles. These rankings assigned by the teacher were correlated with Forms AX and BX of the Hunter Science Aptitude Test. These Pearson product-moment correlation coefficients (combined through Fisher's z transformation procedure) are presented in Table 4.

Table 4

Correlations between Form AX and Form BX of the Hunter Science Aptitude Test and the Science Teacher's Ranking of Science Classroom Performance

	Class 6-7X (N = 28)	Class 6-7Y (N = 30)	Combined (N = 58)
Form AX	$\neq.62^{*}$	$\neq.71^{*}$	$\neq.67^{*}$
Form BX	$\neq.56^{*}$	$\neq.77^{*}$	$\neq.68^{*}$

$^{*}p < .01$

The correlation between the two criteria, the weighted composite science achievement scores and the science teacher's rankings, is $\neq.76$ for Class 6-7X and $\neq.79$ for Class 6-7Y.

Since teachers' ratings are notoriously unreliable, predictive validity coefficients presented in Table 4 are also impressively high. These data supply some independent confirmation of the results obtained with the primary predictive criterion of the composite achievement scores.

A question may be raised concerning whether other predictor variables (for example, a measure of intelligence) would not predict science achievement in the classroom as well as the Hunter Science Aptitude Test. Several researchers (e.g., Brandwein, 1951, 1952) have contended that one factor contributing heavily to science potential is high intelligence of the type revealed by success on tests of intelligence. Stanford-Binet (1937 Revision) Intelligence Quotient scores were available for each child in the sample used. These intelligence quotients were derived from tests administered from one to three years prior to the school year during which the science achievement measures were obtained. As indicated elsewhere in this report, these intelligence quotients ranged from 136 to 171, with a median of 151. The Pearson product-moment correlation coefficient between IQ and the predictive validity criterion of weighted, composite achievement scores is $\neq .21$ ($p > .05$). Thus, there is a statistically significant

difference ($p < .01$) between the degree to which the Hunter Science Aptitude Test and the Stanford-Binet Intelligence Quotient can predict science achievement in the classroom.

Stanford-Binet Intelligence Quotients predict the science teacher's ranking of science accomplishment even more poorly than they predicted classroom science achievement. The Pearson product-moment correlation coefficients between IQ and science teacher's rankings were $+.08$ and $+.10$ for the two classes. The combined coefficient of $+.09$ is not significantly different from zero.

There are a number of interpretations possible to explain these weak relationships between verbal intelligence (as measured by the Stanford-Binet Scales) and science achievement. The range of IQ scores is greatly restricted. Also, these IQ scores were obtained from one to three years earlier than the science achievement scores, while the scores for the Hunter Science Aptitude Test were obtained immediately prior to the school year during which achievement information was gathered. For whatever reason, however, the Hunter Science Aptitude Test is a significantly better predictor of science achievement than Stanford-Binet IQ.

A second question may be asked concerning the likelihood that some third, extraneous variable (for example, verbal ability) is responsible for the high relationship between the Hunter Science Aptitude Test and the criteria employed. Since verbal ability seemed the most plausible extraneous variable of this kind, an attempt was made to eliminate statistically its effect on the relationship between the science aptitude test and the achievement criterion. Since studies of the factorial composition of items in the Stanford-Binet Scales have indicated that they are heavily weighted with verbal ability (especially at the younger age levels), partial correlation coefficients were computed between the Hunter Science Aptitude Test and the weighted composite achievement score with the influence of Stanford-Binet IQ held constant. For Forms AX and BX the partial correlation coefficients are $+.76$ and $+.74$, respectively. These coefficients represent only negligible reductions in the validity coefficients ($+.77$ and $+.74$, respectively, for Forms AX and BX) obtained when verbal intelligence was allowed to vary.

Since clear-cut and consistent sex differences in science knowledge and achievement have been found at the secondary school and college levels and beyond (e.g., Edgerton and Britt, 1944, 1947), an analysis of possible sex differences in science aptitude and achievement in elementary school children was performed in the present research. Consistent with previous evidence, the mean score of the boys (N = 25) exceeded the mean score of the girls (N = 33) on all three science measures (i.e., Forms AX and BX of the Hunter Science Aptitude Test and the composite science achievement test); however, none of these three differences reached statistical significance.

Discussion

Although the reliabilities of the Hunter Science Aptitude Test are only moderately high, the predictive validity data indicate the great promise of this test in predicting science achievement among gifted elementary school children. For this sample of 58 children six and seven years of age, the two forms of the aptitude measure administered at the beginning of the school year displayed an almost perfect predictive relationship to measures of classroom science

achievement compiled throughout the course of the school year. It seems likely that these very strong relationships may be partly explained by the manner in which the tests were constructed and followed up.

In gathering material for items to include in the Hunter Science Aptitude Test, the third-grade course of Science study was carefully observed and analyzed. The content of the 182 items in the aptitude tests was often modelled upon the science concepts and material included in the third-grade syllabus and in science classes. Although the Hunter Science Aptitude Test goes beyond the specific third-grade science content, it is founded upon subject matter drawn from areas of science with which the child is familiar by the third grade or to which he is exposed while in the third grade at Hunter College Elementary School.

The composite science achievement score used as a criterion constitutes, of course, a direct representation of the actual science material covered in third grade. Since the Hunter Science Aptitude Tests are derived in part from analyses of third-grade science content, and the science achievement measure is a direct representation of such content, strong overlapping at the definitional level is to be expected.

Thus, the exceptionally high correlations obtained may be partly understood as a reflection of the fact that the same (or closely similar) kinds of abilities are measured in both aptitude and achievement tests. This fact does not reduce the potential importance of the data obtained in this study, but makes certain extensions of this research especially compelling.

First, in further work with the Hunter Science Aptitude Tests, it will be crucial to go beyond the short-range predictive validity criterion of classroom science achievement used in the study. Although science classroom performance is perhaps the most pertinent predictive criterion for an aptitude test used with six- and seven-year-old children, additional predictive criteria must be added. These additional criteria must extend beyond the present predictive criteria in both time and scope. If, for example, the present sample of children could be followed in their science classroom performance through subsequent elementary and secondary school grades, the duration of time over which accurate predictions can be made from the Hunter Science Aptitude Test could be assessed. Such long-range follow-up would have the additional advantage of including science

content that is not directly represented in the Hunter Science Aptitude Test; thus, prediction could be extended in both time and scope. This approach would circumvent any issues raised by overlap at the definitional level between the aptitude tests and the current predictive validity achievement criterion. Since a portion of the present research grant will remain unexpended at its termination, further follow-up of the sample of children employed in this research could possibly be accomplished without additional allocation of research funds.

Thus, the evidence of an extremely strong predictive relationship presented in this study leads directly to the use of criteria of science accomplishment which are broader in scope and longer in duration. Optimally, such criteria would include evidence of actual creative professional accomplishment in science; extremely long-range analyses of this type would be of great value in evaluating tests administered to groups of very young children.

A second extension implied in the highly significant results of this study is the need for additional validity data, based on samples of both gifted and normal children. Additional classes of children at the Hunter College

Elementary School can be used for subsequent validity studies among gifted children. Somewhat modified versions of the Hunter Science Aptitude Test, applied to representative samples of American elementary school children, would allow the evaluation of its potential usefulness in the area of greatest need. It would be of great educational and social utility to possess techniques for identifying children with exceptional science potential in typical school populations.

Summary

The purpose of this research was to construct an instrument for the identification of science talent and potential in young elementary school children and to validate it. The specific hypothesis tested was that measures of science talent which will allow prediction of future scientific achievement can be constructed and utilized with six- and seven-year-old children.

Two forms of a 91-item Hunter Science Aptitude Test were constructed. The items included in these tests were designed to measure (1) the ability to recall scientific information, (2) the ability to assign meaning to observations, (3) the ability to apply scientific principles in making

predictions, and (4) the ability to use the scientific method. Both forms of the test were administered at the beginning of the school year to each child in a sample of gifted six- and seven-year-old elementary school children drawn from the Hunter College Elementary School. The resulting scores were kept completely confidential.

The validating criteria were derived from a series of seven tests of classroom science achievement in the third grade. These tests were administered at the completion of each science unit during the course of the entire school year. A single weighted composite science achievement score was obtained for each subject.

The parallel-forms reliability coefficient of the Hunter Science Aptitude Test was .64. The reliability of the weighted composite science achievement score was .82. Although these reliabilities are somewhat lower than desired, the predictive validity correlation coefficients were extremely high, essentially the maximum possible relationships given the reliabilities of the tests. Form AX correlated with the criterion .77, and Form BX correlated .71. Corrected for attenuation, these validity coefficients were 1.08 for Form AX and 1.00 for Form BX.

These extremely high predictive validity coefficients may be in part attributable to the fact that the Hunter Science Aptitude Tests and the science achievement criterion overlap in the kinds of abilities and content measured. Both were modelled upon the science content of the third-grade science curriculum. This observation makes certain extensions of this research highly desirable. Extensions in time and scope of the criteria as well as additional validation studies in both gifted and representative samples would be of great value.

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Appendix A

Hunter Science Aptitude Test

General Instructions for the Administration of Items in Groups

1. Series should be administered as numbered. In some cases the later series provide answers called for in earlier series.

2. When administering an item, pictures should be placed on the table in front of the child. The child may handle all materials used.

3. When to query:

   When an answer is incomplete and ambiguous.
   If a child gives two answers - one right and one wrong - the Examiner asks which one the child means.
   Do <u>not</u> query when an answer is wrong.

   How to query:

   "Tell me more about it."
   "Tell me what you mean."
   "Tell me that again."

4. Explanations should be given in a conversational manner whenever possible. They should not seem like a lecture or a constant evaluation of the child's performance.

   When the child's answer is correct and complete the Examiner says "yes," or "that's right." The Examiner then repeats the full explanation.

   When an answer is partially correct or incomplete the Examiner should acknowledge the correct part and then give the full explanation.

   If the child gives a wrong answer, the examiner indicates that it is incorrect and gives the full explanation.

   No explanation is given for final items in any series.

   If a child has not been attentive or does not seem to understand an explanation, the explanation may be repeated. If the child did not understand a word contained in the explanation, the Examiner may define the word.

   Explanations should not be elaborated upon or revised by the Examiner.

Form B | Series 5 | AIR PRESSURE

Subject_____ Date_____

Class_____ Age_____ Examiner_____

	Question	Answer	Score
A.	"What do we call a space where there is nothing, not even air? Explanation: "A vacuum. It's a place with nothing in it, not even air."	"A vacuum" "Space," "hole"	2 0
B.	Show child two pieces of paper. Give child one. "These pieces of paper are exactly the same. Crumple this one into a ball. Now is one paper heavier than the other?" Explanation: The papers weight the same amount. The crumpled paper weighs the same amount as it did before you crumpled it. It's still the same piece of paper."	 "No" "Yes"	 2 0
C.	Show the child two pieces of paper, one crumpled, one uncrumpled. "Now watch what I do." E drops both papers to the floor from table height. "Why does this piece of paper take longer than the crumpled one to reach the floor?" Explanation: "The flat one has a larger surface, there is more air pushing on it as it falls."	 Child indicates (1) greater surface area - more "pushing" room for air, and (2) air pushes against paper Either part alone Neither part	 2 1 0
D.	Show child the same two pieces of paper. "If we were to drop both of these papers in a vacuum would the crumpled one reach the floor first?" If child answers "No" E asks "Why not?"	 No. (Q) "There is no air to push on paper." No. (Q) Incorrect reason given. Yes	 2 0 0

Appendix B.

SCIENCE ACHIEVEMENT TEST I

(Water - Its Importance in the World; Techniques for Purification)

1. Water is used for

(a) (a) growing plants

(b) cooking

(c) washing

Which one of these do you think is most important?

2. Water is also used for

(c) (a) putting out fires

(b) turning water wheels

(c) quenching our thirsts

Which one of these do you think is most important?

3. How much of a vegetable is made of water?

(a) (a) most of it

(b) about one-half of it

(c) less than one-half of it

4. How much of you is water?

(b) (a) 50%

(b) 70%

(c) 90%

5. Which is the best way to find out if a substance has water in it?

(b) (a) Squeeze the substance and see if you can collect drops of water from it

(b) Heat the substance and see if you can collect drops of water from it

6. The water you drink has

(b) (a) a definite taste

(b) no taste

(c) a little taste

7. Most of our water comes from

(b) (a) the ground

(b) rain

(c) reservoirs

(d) the oceans

8. What happens to the heavy soil that streams carry down the mountainside?

(a) (a) it ends up on the bottom of a lake or pond

(b) it keeps floating

(c) it kills the fish in the lake or pond

9. When a pond or lake is first selected to be used as a water supply, it is called a

(b) (a) mud hole

(b) settling basin

(c) reservoir

10. A filter bed is a good place to

(b)
(a) go to sleep
(b) send your unclean water through
(c) drill a well to find water

11. A filter bed helps to

(a)
(a) make water clearer
(b) make water absolutely pure
(c) kill all the bacteria in water

12. How long must you boil water in order to make it safe to drink?

(b)
(a) 10 minutes
(b) 20 minutes
(c) one hour

13. When you distill water you take away

(c)
(a) minerals
(b) dirt
(c) everything but the water

14. One of the best ways to purify your own water is to

(b)
(a) strain it
(b) put a certain chemical tablet in the water
(c) boil it for ten minutes

15. Before you can have distilled water, the water must

(c)
(a) boil
(b) turn to steam
(c) turn to steam and back to water

TRUE-FALSE:

T 16. T F Almost all materials have water in them.

F 17. T F Water is said to be colorless because you can see through it.

T 18. T F Water by itself has no odor, but material sometimes present in water may give the water an odor.

F 19. T F It is safe to drink water that was taken from a mud puddle and then filtered.

T 20. T F Filtering water gets rid of a muddy color.

F 21. T F Water in our reservoirs is pure.

SCIENCE ACHIEVEMENT TEST II:

Water - How Water is Used for Cleaning Purposes.

1. Most dirt particles are held together by

(c) (a) air

(b) water

(c) oil

2. When you pour soap, oil, and water into a test tube but do not shake them up, which is lightest and floats on top

(c) (a) soap

(b) water

(c) oil

3. When you shake up the soap, oil, and water, which of the following things happen?

(b) (a) most of the soap attaches itself to the water

(b) most of the soap attaches itself to the oil

(c) most of the water attaches itself to the oil

4. When you clean something with soap and water, what does the soap do?

(b) (a) flushes the dirt out and carries it away

(b) removes the fat or oil around the dirt

(c) attracts the dirt to itself and takes it away from the thing being cleaned

5. Water is needed along with the soap in cleaning because water

(b) (a) is hot and breaks up the dirt

(b) flushes the dirt out and carries it away

(c) breaks up big pieces of fat into smaller pieces

6. Hard water is water that

(a) (a) does not give a lather to soap

(b) can not be drunk

(c) has no minerals in it

7. When you mix oil and water together (without soap) and let the mixture stand for five minutes, the oil

(c) (a) sinks to the bottom

(b) stays mixed throughout the water

(c) rises to the top

8. What can you do to hard water to make it give a lather to soap

(a) (a) put a water softener in it

(b) boil it

(c) put oil in it

9. You want to wash something but you only have hard water. Do you

(b) (a) first add soap and then add something to soften the water

(b) first add something to soften the water and then add soap

(c) add soap and something to soften the water at the same time

TRUE-FALSE:

F 10. T F Water alone, without soap, can still be good for cleaning.

T 11. T F Dirt is usually attached to clothing by a thin film of fat or oil.

F 12. T F Soap is the only substance there is that breaks up fat into small pieces.

T 13. T F Water alone is poor for washing because it will not dissolve the fat that holds the pieces of dirt together.

F 14. T F Soap and hard water are as good for cleaning as soap and soft water.

T 15. T F Hard water changes soap into a useless, curdy substance.

T 16. T F Washing soda will change hard water into soft water.

F 17. T F The minerals that make water hard also make it undrinkable.

T 18. T F Soft water has different minerals dissolved in it than hard water.

F 19. T F You can tell the difference between hard water and soft water by tasting them.

T 20. T F You can make soft water hard by putting certain minerals into it.

SCIENCE ACHIEVEMENT TEST III:

Water - Forms in which Water Appears in Air.

1. Evaporation means the changing of

(a) (a) a liquid to a gas

(b) a solid to a liquid

(c) a gas to a solid

2. You can speed up the evaporation of water by

(b) (a) putting ice in it

(b) heating it

(c) keeping it in a tightly sealed jar

3. Which of the following increases the speed of evaporation?

(b) (a) the stars

(b) the sun

(c) the moon

(d) the planets

4. Condensation means the changing of

(c) (a) a solid to a gas

(b) a liquid to a solid

(c) a gas to a liquid

5. When water condenses, it generally forms

(c) (a) steam

(b) water vapor

(c) droplets of water

6. Warm, moist air generally

(a) (a) rises

(b) falls

(c) stays in one place

7. Alcohol baths have been used to treat people with high fevers because alcohol baths have a cooling effect. Alcohol baths cool you because

(b) (a) alcohol evaporates slowly

(b) alcohol evaporates rapidly

(c) alcohol condenses slowly

(d) alcohol condenses rapidly

8. A cloud forms when water

(a) (a) condenses

(b) evaporates

(c) is aerated

9. When someone who wears glasses comes indoors after a walk outside on a cold day, his glasses may become clouded. This happens because of

(c) (a) evaporation

(b) vaporization

(c) condensation

10. When you put ice in a jar of water, moisture forms on the outside of the jar. Where does this moisture come from?

(b) (a) the water inside the jar

(b) the air outside the jar

(c) the ice inside the jar

TRUE-FALSE:

T 11. T F Dew is condensed water vapor.

F 12. T F Frost is frozen dew.

T 13. T F Except for location, fogs and clouds are the same thing.

F 14. T F Snow is frozen rain.

F 15. T F All liquids evaporate at the same rate.

T 16. T F Steam is water vapor.

T 17. T F Plants give off water vapor into the air.

T 18. T F Clouds are formed when water vapor in the air is cooled and forms droplets.

F 19. T F Cold air can hold more water than warm air.

F 20. T F Evaporation has a warming effect.

T 21. T F Water can exist in three forms: gas, liquid, and solid.

T 22. T F Sleet is frozen rain.

F 23. T F We can sometimes see water vapor.

F 24. T F To change a gas into a liquid, the gas is heated.

T 25. T F Condensation is the opposite of evaporation.

SCIENCE ACHIEVEMENT TEST IV:

Water - Archimedes Principle

1. If a stone is dropped into a pail of water, the water level

(a)
(a) rises
(b) stays the same
(c) falls

2. In our experiment in class with floating objects we used a catch can. What did we have to find out about this catch can itself?

(b)
(a) how much it holds
(b) how much it weighs
(c) what its shape is

3. In our experiment, when we put an object into the drip can some water flowed into the catch can. What did we have to find out about this water in the catch can?

(b)
(a) how much water there was
(b) how much the water weighed
(c) where the water came from

4. A block weighs 10 grams out of water. The water it displaces weighs 20 grams. What part of the block will float <u>above</u> the water?

(b)
(a) none
(b) about half
(c) all of it

5. A hollow metal ball weighs more than the water it displaces. When this ball is placed on top of a tub of water, will it

(c) (a) float?

(b) sink part way?

(c) sink all the way?

6. When an object is lowered into water, it

(b) (a) becomes heavier

(b) becomes lighter

(c) stays the same

TRUE-FALSE:

F 7. T F All large things float and all small things sink.

T 8. T F It is easier to lift up a person when he is in water than when he is in air.

T 9. T F If an object weighs more in air than the water it displaces, the object will sink.

T 10. T F An object sinks because its weight is greater than the weight of the water it displaces.

F 11. T F To make a submarine come up from the bottom of the ocean, you must make it heavier than the weight of the water it displaces.

T 12. T F An ocean liner floats. It must be lighter than the water it displaces.

T 13. T F It is easier for a person to float in salt water than in fresh water.

F 14. T F Wood that has been soaked in water floats more easily than dry wood.

F 15. T F "Buoyancy" is the pushing-down force of water that makes an object sink.

F 16. T F When a ship sinks, it usually goes only part way to the bottom of the sea.

T 17. T F When an object is placed in water, gravity pulls it down while water pushes it up.

T 18. T F If the downward pull of gravity upon an object is less than the upward push of water, the object will float.

SCIENCE ACHIEVEMENT TEST V:

Water - Water Pressure,

Water Seeks Its Own Level,

The Cartesian Diver

1. The Cartesian diver floats level with the top of the water in jar (illustrate) when there is

(c) (a) more water than air in it

(b) less water than air in it

(c) about the same amount of water as air in it

2. The Cartesian diver sinks to the bottom (illustrate) when there is

(a) (a) more water than air in it

(b) less water than air in it

(c) about the same amount of water as air in it

3. The Cartesian diver behaves most like a

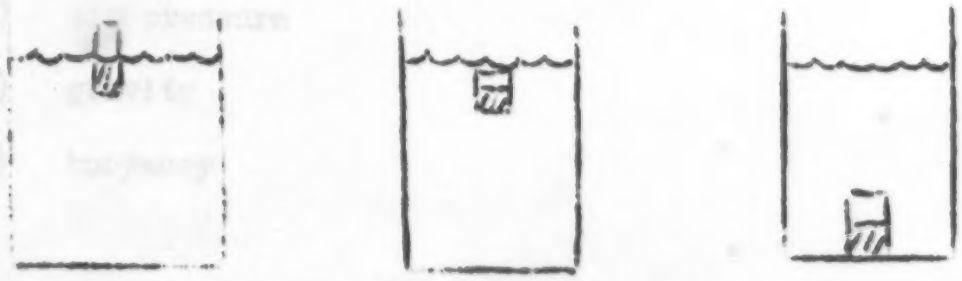
(b) (a) sinking ship

(b) submarine

(c) person diving

4. Which of these would make the easiest diver to operate?

(b) (a) (b) (c)



5. The Cartesian diver sinks when you

(a) (a) make it heavier

(b) push it down by pressing on the top of it

(c) force water out of it

6. You have two tanks of the same size. One is filled with fresh water, the other with salt water. The water pressure will be

(b) (a) greater in the fresh water

(b) greater in the salt water

(c) the same in both

7. When the Cartesian diver is at the bottom of the jar and you stop pushing on the top of the jar, the diver comes to the top because

(c) (a) there's more air in the diver

(b) there's less air in the diver

(c) the air pushes some water out of the diver

8. Dams are built strongest at the

(a) (a) bottom

(b) middle

(c) top

9. The water in a water tank atop a building flows down mainly because of

(b) (a) air pressure

(b) gravity

(c) buoyancy

10. People often put up water tanks because their homes are located

(a) (a) higher than their water supply

(b) lower than their water supply

(c) the same level as their water supply

TRUE-FALSE:

T 11. T F Water pressure depends on the depth of the water above.

F 12. T F Density of water has no effect on water pressure.

T 13. T F Water pushes in all directions.

F 14. T F Water can easily be squeezed into a smaller space.

F 15. T F Water pressure is lowest at the bottom of a tank.

T 16. T F If you try to squeeze more water into a bottle than it normally holds, the bottle may break.

SCIENCE ACHIEVEMENT TEST VI:

Water - Surface Tension

Cohesion and Adhesion

1. Many times a "skin" is formed on top of the water. This is called

(b)

(a) adhesive action

(b) surface tension

(c) attraction

2. Some scientists say that this skin is formed because

(a)

(a) the water molecules at the top are attracted to each other

(b) the water molecules at the top are attracted by the molecules of the air

(c) the water molecules are attracted to the container

3. Chicken wire floats on top of the water because

(c)

(a) it is light

(b) its holes are filled

(c) surface tension holds it up

4. You can prove that oil has surface tension because oil

(b)

(a) spreads quickly

(b) forms round drops

(c) mixes easily

5. Water clings to itself because of

(b)

(a) adhesion

(b) cohesion

(c) condensation

6. Adhesion means that

(a) (a) molecules of one substance or material will cling to the molecules of another substance or material

(b) molecules of one substance cling to each other

(c) molecules will cling to anything

7. The effect of cohesion is shown best by the water molecules

(a) (a) at the top of a container

(b) in the middle

(c) at the bottom

8. A drop of water clings to a pencil because of

(c) (a) cohesion

(b) magnetism

(c) adhesion

(d) gravity

9. Big round drops of water slowly flatten out because of

(b) (a) surface tension

(b) gravity

(c) evaporation

10. On a rainy day you are sleeping under a canvas tent, when you accidentally touch the canvas and water starts to drop in through the spot you touched. This happens because

(c) (a) you have weakened the canvas itself

(b) you have strengthened the surface tension of the water

(c) you have broken the surface tension of the water

TRUE-FALSE

F 11. T F When you float a cork on water it always goes to the side of a container.

T 12. T F Soap bubbles keep their shape because of surface tension.

F 13. T F Some liquids have no surface tension at all.

F 14. T F Soap or detergent strengthens the surface tension of water.

T 15. T F A duck's feathers do not absorb water because the feathers are oily and water does not wet an oily surface.

F 16. T F When you take your hands out of water, some of the water clings to your hands. It clings because of cohesion.

T 17. T F A water bug can skate on top of water because he is held up by the surface tension of the water.

F 18. T F Cohesion is stronger in gases than in liquids.

T 19. T F When the surface tension of a liquid is decreased, the liquid will wet things more easily.

T 20. T F A razor blade will float, if it is placed properly upon water, because of surface tension.

SCIENCE ACHIEVEMENT TEST VII:

SOUND - VIBRATION AND TRANSMISSION

1. How can you tell whether a tuning fork will vibrate fast or slow?

(b) (a) by what it is made of

(b) by how big it is

(c) by how much it weighs

2. The number on a tuning fork represents (Show tuning forks)

(c) (a) its weight in ounces

(b) its length in inches

(c) how many vibrations it makes per second

3. Which tuning fork has the largest number on it?

(a) (a) the short one

(b) the long one

(c) the medium one

4. Which tuning fork vibrates the slowest?

(b) (a) the short one

(b) the long one

(c) the medium one

5. The pendulum experiment showed us

(b) (a) that sound is caused by vibration

(b) how to count vibrations

(c) why things vibrate

6. When we made the pendulum shorter it vibrated

(b) (a) slower

(b) faster

(c) the same as it did before

7. When you plucked the tongue depressor you got a lower sound when it stuck out

(a) (a) farthest from the table

(b) least from the table

(c) halfway from the table

8. About the lowest sound we can hear vibrates at

(c) (a) 5 times per second

(b) 10 times per second

(c) 20 times per second

TRUE-FALSE :

F 9. T F Some sounds are not caused by vibrations.

F 10. T F You usually hear thunder after you see lightning because sound travels faster than light.

T 11. T F You can only hear certain vibrations.

T 12. T F A dog can hear better than you can.

F 13. T F When sound strikes your ears, it stops the vibration in your eardrums.

T 14. T F Sound can travel through solids, liquids, and gases.

T 15. T F An echo is made when the side of a hill or a wall bounces back vibrations.

F 16. T F Most people can hear vibrations close to 30,000 times per second.

T 17. T F All vibrations make sound.

T 18. T F When you talk or sing, the voice box in your throat vibrates.

F 19. T F Each object that vibrates makes a different sound.

T 20. T F A vacuum is a space without any air. A sound can not travel through a vacuum.